Journal of Advances in Mechanical Engineering and Science, Vol. 3(3) 2017, pp. 1-8

RESEARCH ARTICLE

Multi-Tool Design and Development of Operating Machine

J Sreedhar[1], *B Sanjanna[1], K Nageswara Rao[1], K.P Reddy[1]

[1]Asst.Professor, Department of Mechanical Engineering, Sreyas Engineering College, Nagole, India.

Received- 7 March 2017, Revised- 10 May 2017, Accepted- 2 June 2017, Published- 28 June 2017

ABSTRACT

The world being led by innovations has headed to the accomplishment of the activities that we encounter in our day to day life to be snappier and quicker. Yet, this progression additionally requests high level investments as well as expenditures. Each and every industry is striving to make productivity at a higher rate, at the same time maintaining product's quality and product's standard to be of a normally low cost. In this work proposed, a conceptual prototype of a machine that would be fit to perform distinctive operation simultaneously was developed. The proposed system includes the feature of being more economical too. Scotch yoke is a technique that is intended for the purpose of sawing and shaping activities and this proposed work relies on the main shaft upon which the scotch yoke is attached directly. A bevel gear system to transmit power at one area is available on the main shaft. The drive to drilling is offered by means of the bevel gear. Throughout, the bevel gear drive, is utilized for drilling. With the help of a motor, a force is given to the two sided bearing block which has grinding at one end and circular cutter at the other end. This model helps us to acquire the functionalities performed at various working centres concurrently as the force is obtained from a single power source. It is simple in construction and easy to operate. The main goals of this proposed model are conserving electricity, minimizing cost that is related to power utilization, enhanced production and reduction in floor space.

Keywords: Scotch yoke, Bevel gear system, Drill bit, Bearing block, Grinding wheel.

1. INTRODUCTION

A significant part of the investment is usually used up for installation purposes in machines. Therefore the work proposed was envisioned in such a way that the operations like drilling, sawing, shaping, grinding and other lathe functionalities do not consume additional costs for such operations. Various machining process in manufacturing industries are carried out by separate machining devices. It needs more space and time that involves high expenses [1]. But the fabrication of multi-tool operating mechanical device encompasses five operations on a single machine. The operations are categorized as drilling, cutting, shaping, grinding and circular sawing. It is a new concept specially meant to reduce the work time and save the cost. Instead of using a shaping machine, a special arrangement for shaping operation which is involved in the drilling machine, is also used for the cutting operation. This is done to save the added investment cost that occurs during drilling and shaping the device in the industries. The machine operates the drilling machine with the bevel gear arrangements. Hence we can carry out exactly the above mentioned five operations on the machine. Driller, bevel gear, drill bit, chuck, bearings, slotting tool, shaping tool and grinding wheel are the significant parts of the machine.

1.1. Machine

A machine is composed of mobile and immobile parts. These parts are united to create, transform or to use the mechanical energy. These machines are comprised of many elements and every element is an isolated part of the machine, where the elements are to be designed independently and

*Corresponding author. Tel.: +919494797320
Email address: bandarisanjay1@gmail.com (B.Sanjanna)
Double blind peer review under responsibility of DJ Publications
https://dx.doi.org/10.18831/james.in/2017031001

assembled together [2]. Every element is a constituent of a whole part or it can be made of many small pieces that are combined to form a machine by means of processes like riveting, welding, etc. [3, 4]. Many machinery parts are joined together to create a machine as a whole. Examples of some of the machines are, lathe which uses mechanical energy to cut the metals, turbines which create mechanical energy, compressors that compress the air by utilizing mechanical energy, engines that take up fuel to create mechanical energy, refrigerators and AC which utilize mechanical energy to create a cooling effect and washing machines that use up the mechanical energy to cleanse the clothes [5, 6].

1.2. Classification of machines

Machines are categorized into following types.

- Machines that produce mechanical energy:

  The machines that produce mechanical energy are coined as prime movers. These machines transform certain forms of energies such as heat energy, hydraulic energy, and electrical energy into mechanical energy or work. The exact pioneer of such machines is the IC (Internal Combustion) where the fuel's chemical energy is transformed into heat energy [7]. This heat energy is thereby transformed into mechanical work that causes rotation of the vehicle's wheels. Gas turbines, water turbines and steam engines are some of the list of machines that fall under this category.
- Machines that transform mechanical energy:

  These machines are coined as converting machines as they transform mechanical energy into forms of energies like electrical energy, hydraulic energy and so on. Electrical generators, where the rotation of the shaft is transformed into electrical energy, and hydraulic pumps where the rotor's rotational energy is transformed into fluid's hydraulic energy are certain illustrations.
- Machines that use mechanical energy:

  In these machines the mechanical energy that is obtained is used for several applications. Some examples of such mechanisms are lathe machines which cut the metals and washing machines which makes use of rotor's rotation for washing.

2. WORKING PRINCIPLE

A force is in fact given to the main-shaft in this device, at the place where the scotch yoke is attached directly. The main intention of the scotch yoke is to perform the operations of sawing and shaping. A bevel gear system is made use of to transmit power at one area. The bevel gear provides a drive for drilling. The motor offers a drive to the two sided bearing block. One end of the bearing block will perform the grinding operation and the other end will have a circular cutter. This prototype supports in obtaining the functionality at various working centres at the same instance. As mentioned earlier, it is easy to operate. Our proposed work usually functions on two principles alone. In the case of the "multi-tool operating mechanical machine" a supply to the main-shaft is given as a movement made along the axial shaft that has been mounted on the bevel gears. By the pinion shaft, a drive is provided to the drill shaft by belt-pulley arrangement. An installation of the stepped pulley is made in the arrangement. So, an alteration in the speed is made. As a motion is made along the axial shaft, a double sided bearing arrangement is used. This supports in providing the force that is required in grinding operations and also in operations that involve the circular saw cutter. Because the scotch yoke mechanism is fabricated to the main-shaft in a direct manner, it possesses an even angular velocity similar to that of the main-shaft.

2.1. Scotch-yoke mechanism

A harmonic movement which is very clear and straightforward is formed by the scotch-yoke mechanism, if it is driven by an eccentric or crank.

The pioneer usage of this mechanism was on steam pumps though it is not suited for high speeds because of backlash that persists in the scotch yoke. In these days, this mechanism is principally utilized in applications involving computing where harmonic activities are needed.

The scotch yoke is a process which finds itself in transforming the slider's linear motion into rotational motion or vice versa. A reciprocating part or a piston makes a direct coupling to a sliding yoke by means of a slot that involves a pin present on the rotating part. The motion of the piston that exhibits a shape is clearly a sine wave which over time provided a speed which is of a constant rotation. The closer view of scotch yoke mechanism is shown in figure 1.

Figure 1.A closer view of scotch yoke mechanism

2.2. Power transmission through gear

Bevel gears are the gears where the two axial shafts intersect, and the tooth-bearing faces of the gears are in the shape of a cone. Bevel gears are mostly placed on shafts that are separated at a distance of 90°. Yet it was employed to function at other angles too. The gear’s pitch surface acts as the imaginary toothless surface by separately averaging out the teeth’s peaks and valleys. The typical gear’s pitch surface corresponds to the cylinder’s shape. The gear’s pitch angle is the angle amidst the axis and the face of the pitch surface. Pitch surface and the pitch angle are the two crucial gearing notions.

The most common variety of bevel gears have pitch angles which are below 90° and so they exhibit a conical shape and this kind of bevel gears are known as external, as the gear’s teeth are seen pointing outwards. The meshed external bevel gears’ pitch surface is coaxial together with the gear shafts. The point of intersection of the shaft axes is of great significance. The apexes of the two surfaces are at the above mentioned intersecting point. Bevel gears possess pitch angles above 90° and possess teeth that are seen pointing inwards. And so they are called as internal bevel gears. The specification of the components used is expressed under table 1.

Table 1.Specification of the components

Components	Specifications
Frame’s model	length = 3.5 feet width = 3 feet height = 3.5 feet
Bevel gears	T1 = 40, T2 = 20 (two teeth) material = mild steel
Gear	base radius = 80 mm pitch cone angle = 55° pitch diameter = 4 cm
Pinion	base radius = 42 mm pitch cone angle = 35° pitch diameter = 2.8 cm
Shaft	diameter = 25 mm length = 2.7 feet material = mild steel
Roller bearings	inner diameter = 25 mm
Belt	material = V-belt length of 1st belt = 96″ length of 2nd belt = 46″
Pulley	diameter = 457.2 mm
Frame	iron
Operations	sawing / cutting, shaping, drilling, grinding and circular saw cutter

2.3. Functionalities of a machine

The overview of the model is expressed under figure 2.

Figure 2.Overview of the model

2.3.1. Drilling

The functionality that involves in causing a hole into the work-piece by the aid of a rotating cutter is called drilling and the rotating cutter device used is referred as drill. This function can be performed in lathe. Here the drill is kept in tailstock and the operation is kept by the chunk. The popularly utilized drill is the twist drill. It is a simple and precise machine that is used in the production shop. The work-piece is kept unmoving. The clamp is kept in a position and the drill alone makes a rotational movement to make a hole. The sensitive or bench drilling machine is utilized for simple works. The vertical column has a swivelling table, that is developed such that the height of the table can be changed depending on the height of the work-piece. Depending upon the position needed, the table can be oscillated. At the column's apex, two pulleys are present and they are attached by means of a belt. Amidst them, one pulley is placed on the motor shaft and the other pulley is mounted on the machine spindle. The operator causes a perpendicular movement to the spindle by the aid of feed handle. The operator experiences a cutting action. The holes are drilled in the range of 1.5mm to 15mm. Figure 3 shows drilling centre through bevel gear arrangement.

Figure 3.Drilling centre through bevel gear arrangement

2.3.2. Grinding

Material removal and surface generation are the processes involved in grinding process that is intended to shape and finish the components that are created by metals and other materials. The exactness of the operation and the surface finish obtained by grinding process exhibit performance of up to 10 times when compared to turning or milling process. The operation of grinding and circular saw cutter centre getting power through belt drive arrangement is expressed under figure 4. Figure 5 shows sawing/ cutting and slotter end operations using scotch yoke mechanism.

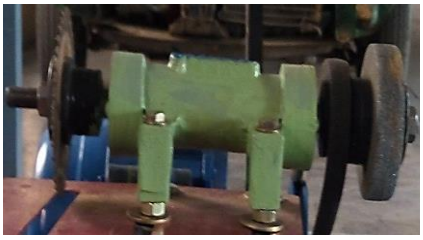

Figure 4.Grinding and circular saw cutter- belt drive arrangement

Figure 5.Sawing/ cutting and slotter end operations using scotch yoke mechanism

Grinding makes use of an abrasive product. The product used by the grinding machine is generally the rotating wheel. The wheel which is rotating experiences a controlled contact with the work surface. The wheel in the grinding machine is called as the grinding wheel, which is created by abrasive grains that are kept together in a binder. These grains possess a similar functionality as that of the cutting tools which involve in removing tiny chips of material that are generated during the operation. When the abrasive grains become torn and worn out, the additional resistance causes fracture to the grains and deterioration to the bonds. The pieces which are dull, break. And only those that are fresh exposing sharp grains endure the cutting operation. The necessities for an effective grinding involve:

- Components those are abrasive must be harder than the operation involved.
- Abrasive wheels must be resistive to shock and heat.

Powdered abrasives have the ability to control fracturing. Abrasives are used in industries. The commonly used abrasives in the industrial fields are generally synthetic in nature. The foremost usage of aluminium oxide is found in the grinding activity of ferrous metals and this chemical compound is made use in three quarters. The chemical compound silicon carbide is utilized for the grinding purpose of softer, non-ferrous metals as well as high density materials like cemented carbide or ceramics. Cubic Boron Nitride (CBN) as well as diamond is coined as "Super abrasives" and these sorts of abrasives are utilized for about 5 per cent of the grinding operation. Ferrous materials that are hard are crushed with CBN whereas non-ferrous materials and non-metals are crushed to the maximum extent possible with diamond.

The process finds it necessary to signify the grain size of abrasive materials. The coarse grains that are large in size remove materials sooner whereas the grains that are of smaller size exhibit a smoother finish. The abrasive grains are held by the help of the binders. The binder includes the following:

- Vitrified bonds which are glass-like bonds synthesised using fused clay or feldspar.
- Organic bonds obtained from synthetic resins, rubber, or shellac.
- Metal or single-layer bond systems intended for super abrasives.

Wheels are categorized depending upon their strength and wear resistance. A "hard" wheel is a wheel that opposes the individual grains from being separated. One which is very hard will exhibit a slower wear and cause dulled grains to function and overheat them thereby affecting the final finish. If the grains are very soft, a wheel is utilized which sooner will get weak leading to be replaced frequently.

An alternative feature of the grinding wheel is that, their pore structure or density indicates porosity. This pore structure causes a separation of the grains that cause coolant retention and the regions intended for chip formation. Dense wheels are apt for materials that are hard whereas higher densities are much apt for metals that are soft. The size of grain, type of bond, structure of the pore is related to each other. Wheels that are worn and also the wheels that are prone of getting damaged should never be utilized.

Some of the safety precautions that need to be followed to ensure the correct usage of grinding wheels include the following suggestions.

- Before turning on the grinding wheel, machine guards have to be checked.
- In advance to the beginning of the work, the wheels must be run for at least 60 seconds.
- Persistently use eye guards.
- Before utilizing the wheel, correctly balance and dress the wheels.

Dressing and truing of wheels are performed by the help of tools that are intended to do so. Wheel dressing is usually exhibited by manual means amidst work cycles. However, certain grinding machines accomplish the dressing functionality by automatic means. The coolant's usage to accomplish the grinding process is very crucial. Coolants have the ability to diminish the power needs of the grinding machine, maintain the quality of the work, stabilize the part dimensions and also ensure extended life span of the wheel. Coolants are none other than emulsions, synthetic lubricants or superior oils used for the process of grinding. Coolants are used by flooding the working place or by the application of jet streams which are at a high pressure.

3. RESULTS AND DISCUSSION

The factors that govern the selection of the materials are expressed below [8]. The material of choice must contain the required properties intended for the proposed application. The necessary factors that have to be fulfilled are weight, surface finish, rigidity, the ability to endure any environmental conditions [9] that are imposed by chemicals, life span of the tool, reliability, etc. The chief material properties that affect the process of selection are physical, mechanical, chemical and manufacturing properties.

The physical properties that are to be alarmed of are, melting point, thermal conductivity, specific heat, coefficient of thermal expansion, specific gravity, electrical conductivity, effects of magnetism, etc. The mechanical properties that are to be alarmed of are, the tensile strength, compressive shear, bending, torsional and buckling load, fatigue resistance, impact resistance, elastic limit, endurance limit, and modulus of elasticity, hardness, wear resistance and sliding properties.

The manufacturing properties are, cast ability, weld ability, forge ability, features related to surface, shrinkage, deep drawing, etc.

- Manufacturing case: At times the need for the least probable cost to manufacture or the need to ensure better surface qualities that are acquired by the usage of apt coating substances may require the usage of special materials.
- Quality deserved: This usually creates an impact on the manufacturing activities and finally affects the material as well. For instance, going for casting would not be preferable at any cost if there is lesser number of components available as these components can be made much more

economical by means of welding the steel [10].

- Availability of material: Certain materials which are of a minimal supply in turn become mandatory for the designer to make use of some other materials that may never make an exact alternative for the material that is designed. It is very necessary to make a note of the delivery of the material and the date it was delivered.
- Space consideration: At times materials of high strength must be chosen because the forces that are indulged are high and there exist boundaries for spaces.
- Cost: Like other issues that exists with relevance to the choice of material, the material's cost shows a crucial part and it should never be neglected. Sometimes issues like usage of scrap, existence and non-maintenance of the parts fabricated are also indulged in the choice of appropriate materials.

3.1. Calculation

The main goal of the work proposed is to signify an innovative concept. For this, certain useful data are extracted from our theoretical model, and a calculation on the deviation percentage derived from the standard calculated values is deliberated as follows.

3.1.1. Calculation of drilling speed

For drilling speed, first we calculated the speed of bull wheel i.e. the main pulley. From the relation of speed and diameter equation (3.1) can be defined as,

$$Ns/Nm = Da/Db \quad (3.1)$$

where, Ns is the speed of the main pulley, Nm is the speed of the motor which is 1445rpm, Da is the diameter of the motor pulley (small) which is 90mm, Db is the diameter of the main pulley which is 457.2mm.

So, the speed of the main pulley is given under equation (3.2).

$$Ns = (Da/Db) * Nm \quad (3.2)$$

Ns= (90/457.2) *1445

Ns= 284.44 rpm

Therefore, bull wheel speed is 284.44rpm.

Now the drilling speed is calculated, having the values as speed of the bull wheel to be 284.44rpm, no. of teeth on gear to be 40 and no. of teeth on pinion to be 20.

This is done by the relation given under equations (3.3) and (3.4),

$$Ng/Ns = Tp/Tg \quad (3.3)$$

$$Ng = (Tp/Tg) * Ns \quad (3.4)$$

These two equations give the value of the drilling speed as stated below.

Ng = (40/20)*284.44 = 568.88rpm

The verification of the drilling speed is performed as follows. Since we used 1:2 gears, i.e. the gear has 40 teeth, and pinion has 20 teeth, the speed of drilling gets double to that of the speed of the bull wheel. This is verified by the following step.

Ng = 284.44*2 = 568.88 rpm

3.1.2. Calculation of grinding speed

From the relation between the speed and the diameter that derives equation (3.5) and (3.6), the value of Ns is calculated.

$$Ns/Nm = Da/Db \quad (3.5)$$

$$Ns = (Da/Db) * Nm \quad (3.6)$$

where, Ns is the speed of grinding and circular cutter, Nm is the speed of motor, Da is the diameter of pulley used for grinding which is 45mm, Db is the diameter of big pulley of the motor which is of 110mm.

Therefore, Ns = (110/45)*1445, which equals 3532.22rpm. Therefore the speed of grinding is 3532.22rpm.

3.1.3. Calculation of circular saw cutter

As the grinding and circular saw cutter are assembled on the same bearing block, the speed of circular saw cutter is equal to grinding wheel. Therefore, the speed of circular saw cutter (Cs) equals 3532.22rpm.

3.1.4. Calculation of hacksaw cutting speed

Table 2 shows the values of driven end's theoretical and actual revolution.

Table 2.Driven end's theoretical and actual revolution

S. No.	No. of revolutions offered to main-shaft	Driven end's theoretical revolution	Driven end's actual revolution
1	1	1.428	1.335
2	2	2.856	2.67
3	3	4.284	4.22
4	4	5.712	5.65
5	5	7.14	7.075
6	6	8.568	8.503

$$\text{Angular velocity (V)} = w * r \quad (3.7)$$

where, r is the radius of the crank wheel which is 0.1397mts. Angular speed can be,

$$\text{Angular speed (w)} = 2\pi N/60 \text{ rad/sec} \quad (3.8)$$

where, N is the speed of crank wheel in rpm which is 284.44rpm. Therefore from equations (3.7) and (3.8), the following values are obtained.

w = 2*π*284.44/60
w = 29.786rad/sec
V = 29.786*0.1397 = 4.16m/sec
V = 4.16*60 = 249.66m/min.

Therefore, the angular velocity of hacksaw is 249.66m/min.

Table 3.Variation of power transmission difference amongst the theoretical and actual cases

S. No.	No. of revolutions offered to main-shaft	Driven end's theoretical effective stroke length	Driven end's actual effective stroke length
1	1	7.9	7.73
2	2	7.9	7.73
3	3	7.9	7.73
4	4	7.9	7.73
5	5	7.9	7.93
6	6	7.9	7.93

3.1.5. Calculation of shaping speed

Since, the shaping and hacksaw is assembled on the same shaft i.e. on the corners of scotch yoke mechanism, the velocity of shaping will be equal to velocity of hacksaw cutting. Therefore, the velocity of shaping (V2) equals 249.66m/min. Table 3 shows the variation of power transmission difference amongst the theoretical and the actual cases.

4. CONCLUSION

It is clear that all the industries that are based on production, require a lower productivity cost and high work rate which are viable by making use of multi-function operating device that use lesser power and time. As this machine offers functionalities at various centres, it was found to be effective in reducing time that was consumed up-to a considerable limit. When it comes to an industry, a substantial part of the investment is used up for the installation purpose of the device. So in this work, a machine is proposed so that it does the machining functionalities like drilling, sawing, grinding as well as shaping without additional paying for machines that function above the individual tasks for performing simultaneous operations. This project proposed exhibited an exciting task in the arena of industrial as well as automated workshops. It is found to be useful for the workers who work in the service stations of the industrial workshops. This project has been found itself superior in terms of reduction in cost that is usually indulged in the fabrication of the tasks stated for the purpose of the project.

REFERENCES

[1] Heinrich Arnold, The recent History of the Machine Tool Industry and the effects of Technological Change, University of Munich, Institute for Innovation Research and Technology Management, Vol. 14, 2001.

[2] Toshimichi Moriwaki, Trends in recent Machine Tool Technologies, NTN Technical Review, Vol. 74, 2006, pp. 2-7.

[3] Frankfurt am Main, Multi-purpose Machines ensure enhanced Independence, EMO Hannover, 2011.

[4] T.Moriwaki, Multi-Functional Machine Tool, Department of Industrial and Systems Engineering, Setsunan University, Neyagawa, Japan CIRP Annals - Manufacturing Technology, http://dx.doi.org/10.1016/j.cirp.2008.09.004.

[5] N.Austin, Different Refrigerants and their Impact on Vapour-Compression Refrigeration Systems, Journal of Advances in Mechanical Engineering and Science, Vol. 2, No. 3, 2016, pp. 29-39, http://dx.doi.org/10.18831/james.in/2016031004.

[6] S.Muthuraman, S.Kathirvel and Hafiz Zafar Sherif, Investigation of Evaporative-Vapour Compression Refrigeration (VCR) based Air Conditioning (AC) Framework for Warm and Dry Climatic Conditions, Journal of Advances in Mechanical Engineering and Science, Vol. 2, No. 5, 2016, pp. 1-17, http://dx.doi.org/10.18831/james.in/2016051001.

[7] S.Saravanan and M.Ravichandran, Effect of SiC Coating on Fuel Consumption and Emission Control in IC Engines, Journal of Advances in Mechanical Engineering and Science, Vol. 1, No. 2, 2015, pp. 21-27, http://dx.doi.org/10.18831/james.in/2015021003.

[8] Pulak M.Pandey Selecting and Planning the Process of Manufacture, http://paniit.iitd.ac.in/~pmpandey.

[9] R.Pugazhenthi, R.Saravanan and M.Anthony Xavior, A New Heuristic for Modern Manufacturing Environment Scheduling Problems, Journal of Advances in Mechanical Engineering and Science, Vol. 1, No. 1, 2015, pp. 1-11, http://dx.doi.org/10.18831/james.in/2015011001.

[10] P.Bosetti, M.Leonesio and P.Parenti, On development of an Optimal Control System for Real-Time Process Optimization on Milling Machine Tools, Procedia CIRP, Vol. 12, 2013, pp. 31-36.